Potential Interference to NVNG MSS Satellite Receivers: With dynamic channel assignment techniques used by the satellites, Earth-to-space transmissions will be received at the satellites only on channels not being used at that time by LMS transmitters. The potential problem is the availability of a sufficient number of clear uplink channels to provide the needed transmissions within the NVNG MSS. To analyze this situation, a simulation was run to determine the maximum number of LMS transmitters within the satellite beam, that would allow on the average six clear channels available for the satellite uplinks. Multiple worst case conditions were used in the simulation, including: 1) non-GSO MSS MESs transmitting at 100% of capacity 24 hours per day, 2) terrestrial LMS stations and non-GSO MSS MESs geographically clustered in the same areas, 3) satellite beam covering the whole of CONUS (most of the time the satellites will see large ocean areas and a lesser number of LMS stations in the beam because of rapid satellite motion and varying satellite ground tracks.) Four different land mobile station activity factors, three land mobile channelization plans, and three MES uplink data rates were modeled. The results[1] indicate that with 25 kHz land mobile system channelization, 2.4 kbps MES uplink data rate, and .006 Erlang activity factor, 285,000 terrestrial mobile stations could operate within the satellite footprint (12 million $km^2$) and still leave a minimum of 6 clear channels for MES uplink transmission in 5 MHz of shared bandwidth. In 20 MHz of shared bandwidth, there could be about 1.5 million terrestrial stations and 6 clear channels still available for MSS use. Since on the average, only 30% of CONUS is in view of a particular satellite, there could be more than 5 million terrestrial stations in CONUS and an average of six clear uplink channels would still be available.

Information has been supplied on the density of LMS transmitters in the US: 12 million in the re-farming bands near 150 MHz, 450 MHz, and 470-512 MHz, with about 4 million in the 450-470 MHz band[2]. The results cited in the previous paragraph indicate that up to about one million additional LMS transmitters could be accommodated in the 450-470 MHz band and still provide six available channels for MSS uplinks. Greater availability of uplink channels would occur in practice because of several additional factors: 1) non-uniform distribution of LMS transmitters across the 20 MHz, 2) multiple satellites in view much of the time, 3) satellites beams viewing mostly ocean much of the time, 4) acceptable delays in NVNG MSS transmissions to avoid the LMS busy hours. (Within about six minutes, a satellite viewing full CONUS moves to viewing about 50% ocean.) With these factors as variances from the worst case simulations used, it is concluded that there would be a sufficient number of clear channels to provide for the NVNG MSS uplink transmissions in a shared bandwidth of 20 MHz. The simulation results in Ref. 1 for potential LMS interference into MSS satellite receivers were also input to international Working Party 8D of the ITU-R. The Working Party 8D conclusion was that with frequency sharing, as studied, a sufficient number of clear channels (6) could be found for MSS uplinks.

Consider the effect of re-farming the LMS bands and the subsequent reduction in channel bandwidths to 12.5 kHz and 6.25 kHz. Using the simulations in Ref. 1 and the factor of 30% of CONUS in view, the number of mobile station transmitters in CONUS that would allow six clear channels to be found are about 10 million and 25 million, for 12.5 kHz and 6.25 kHz channel bandwidths, respectively, in the band 450-470 MHz.

Conclusion: Co-frequency sharing between LMS systems and NVNG MSS systems has been shown to be feasible under a regimen where the burden of sharing (additional equipment, operational complexity, and new technology) is born entirely by the MSS systems. The LMS systems may continue to operate as if the MSS systems were not in the band at all. The very small decrease in availability (less than 0.1%) would be handled by the existing techniques and procedures currently used by the LMS systems to combat other outages due to, for example, blockage, multipath, rain attenuation, or LMS self-interference.

Analyses and simulations in section 4.4 of the IWG-2A report and the considerations in this concise paper have shown that frequency sharing between NVNG MSS uplinks and LMS stations is feasible in the frequency bands 450-470 MHz. The more difficult sharing situation is the availability of uplink channels for the MSS. Shared allocation of the wide bandwidth (20 MHz) makes this problem solvable.

In the US, with 25 kHz channelization, there are 800 LMS channel slots in the band 450-470 MHz. If each channel is geographically reused only 20 times within CONUS (as assumed in the simulation[1]), 16,000 LMS channels are available in CONUS. For NVNG MSS uplinks with the equivalent of six full-time, clear channels, only 6/16000 or 0.04% of the available LMS channel capacity would be used by the NVNG MSS. And those six equivalent channels would be obtained by short duration, low duty cycle usage in the intervals between LMS messages, with no burden of new technology, complex operational procedures, or additional equipment for the LMS systems. The proposed shared allocation is not an unreasonable request.

A formal proposal for the shared allocation in the band 450 - 470 MHz is in Document IWG-2A/84 of the WRC-97 Advisory Committee. An appropriate footnote(s) similar to S5.286B would need to be added to reflect that the sharing burden would be accepted entirely by the MSS.

References:

1. Document IWG-2A/59 (Rev. 2), "Frequency Sharing Between Non-GSO MSS (Narrowband Earth-to-Space Links) and LMS Systems", Erik Goldman, Mark Sturza, and Ed Miller, October 21, 1996
2. Document IWG-2A/57, "Preliminary Study of Sharing Between Non-GSO MSS Below 1 GHz and Terrestrial Private Land Mobile Systems", LMCC (Land Mobile Communications Council), July 30, 1996

INTERNATIONAL TELECOMMUNICATION UNION

**RADIOCOMMUNICATION STUDY GROUPS**

**Document 8D/TEMP/133-E**
**5 November 1996**
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**Sub-Drafting Group 8D3A-4**

WORKING DOCUMENT TOWARDS DRAFT NEW RECOMMENDATIONS

# METHODS FOR MODELLING FREQUENCY SHARING BETWEEN STATIONS IN THE LAND MOBILE SERVICE BELOW 1 GHz AND NON-GEOSTATIONARY SATELLITE ORBIT (NON-GSO) MOBILE EARTH STATIONS

Attachment 1 - Preliminary draft new Recommendation and Attachment 2 - working document for draft new Recommendation are provided for study and evaluation until the next Working Party 8D meeting.

Attachment 1, "Method for the Statistical Modelling of Frequency Sharing Between Stations in the Land Mobile Service Below 1 GHz and FDMA Non-Geostationary Satellite Orbit (Non-GSO) Mobile Earth Stations", provides a method for using simulation techniques to statistically estimate the probabilities of interference, the mean times between interference events, and the lower bound number of land mobile stations that would allow non-GSO mobile earth stations to find a sufficient number of available Earth-to-space channels to operate in a frequency sharing environment with stations in the land mobile service. The propagation model used is the same as used in ITU-R Recommendation M.1039.

Attachment 2, "A Methodology for Calculating Interference Probability from Non-GSO MSS Mobile Earth Station to Land Mobile Station Operating Below 1 GHz", provides an analytic methodology for calculating interference probability from non-GSO MSS mobile earth stations to land mobile stations, under the circumstances as follows: a) interference from MES stations to base station of the existing LMS station with higher antenna, b) interference not only to LMS stations but also to radio-relay stations of LMS, c) using a propagation model derived from ITU-R Recommendation PN.370-7.

Participants in Working Party 8D are requested to closely examine the two attachments and to consider and evaluate the methodologies, the assumptions, and the technical parameters used to represent the MSS and the LMS systems.

This document is also being referred to Working Party 8A for examination.

Source: Document 8D/150

ATTACHMENT 1

PRELIMINARY DRAFT NEW RECOMMENDATION

**METHOD FOR THE STATISTICAL MODELLING OF FREQUENCY SHARING BETWEEN STATIONS IN THE LAND MOBILE SERVICE BELOW 1 GHz AND FDMA NON-GEOSTATIONARY SATELLITE ORBIT(NON-GSO) MOBILE EARTH STATIONS**

(Questions ITU-R 83-3/8, 84-3/8, and 201/8)

**Summary**

This Recommendation provides a method for using simulation techniques to statistically estimate the probabilities of interference, the mean times between interference events, and the lower bound number of land mobile stations that would allow non-GSO mobile earth stations to find a sufficient number of available Earth-to-space channels to operate in a frequency sharing environment with stations in the land mobile service. The propagation model used herein is the same as used in ITU-R Recommendation M.1039.

The ITU Radiocommunication Assembly,

*considering*

a) that Resolution 214 (WRC-95) invited the ITU-R to study and develop Recommendations on the technical and operational issues relating to sharing between services having allocations and the non-GSO MSS below 1 GHz in the bands proposed to WRC-95 and in other frequency bands;

b) that the spectrum already allocated or being considered for allocation by world radio conferences for low-Earth orbit (LEO) mobile-satellite services (MSS) below 1 GHz, if shared with land mobile services, must provide adequate protection from harmful interference;

c) that LEO MSS can provide beneficial radio-based services to a large community of travellers;

d) that the use of LEO enables practical use of frequencies below 1 GHz by space stations;

e) that some coordination and channelization techniques used in fixed and mobile radio systems in bands below 1 GHz can lead to low Erlang loading on individual channels;

f) that dynamic channel assignment techniques are technically feasible and may provide a means of spectrum sharing between land mobile services and low power, low duty cycle mobile-satellite services;

g) that the users would operate throughout large geographic areas;

h) that the transmission of the MES are short bursts;

j) that the signal characteristics in the MSS below 1 GHz may allow co-channel sharing with mobile and fixed service networks,

*recommends*

1 that the statistical modelling methods described in Annex 1 be used to evaluate frequency sharing between stations in the land mobile services below 1 GHz and FDMA non-geostationary satellite orbit mobile earth stations in the same frequency band.

ANNEX 1

**Statistical Modelling of Frequency Sharing Between Stations in the Mobile Service Below 1 GHz and Mobile-Satellite Service (MSS) Earth Station Transmitters**

## 1 Introduction

This Annex describes a method to be used to determine if mobile-satellite service (MSS) earth station transmitters can share spectrum with land mobile services. Land mobile services in the bands below 1 GHz are typically characterized by voice and data carriers that may be analog or digitally modulated and are assigned on a periodic channel grid. Channel spacings used include 6.25 kHz, 12.5 kHz, and 25 kHz. The MSS systems would perform Earth-to-space transmissions using short-term bursts on an intermittent basis with a low duty cycle. ITU-R Recommendation M.1039 notes that burst lengths might be up to 500 ms and that the time duration of 1% in 1 - 15 minutes has been suggested. MSS systems below 1 GHz may use a dynamic channel assignment algorithm which allows the space station to identify those channels not occupied by the mobile stations which are sharing the spectrum. A receiver in the satellite monitors the entire shared frequency band and determines which segments of the spectrum are currently being used by the LMS system or for non-GSO MSS uplinks. With the band-scanning receiver on board the satellite, there is very little chance for interference from mobile earth stations to land mobile system receivers. There are, however, several circumstances where the dynamic channel assignment technique would fail to identify an active LMS channel: 1) LMS power level below the detection threshold of the satellite band-scanning receiver, 2) blockage on the path from the LMS transmitter to the satellite so the received signal level is not high enough to be detected, 3) a LMS transmitter begins operation on a channel during a MSS transmission on what had previously been measured as a clear channel. The methodology in Section 2 provides calculation of the probability of interference to a LMS receiver from MES transmissions within a single MSS system, given that the dynamic channel assignment technique has not identified an active LMS channel for the reasons given above, or for any other reason.

The other possibility for mutual interference is LMS transmissions interfering into the MSS space station receiver. With the MSS band scanning receiver identifying clear Earth-to-space channels for MES use, this type of interference can be avoided. Section 3 provides a statistical method that can be used to provide assurance of finding a sufficient number of clear channels to carry the MSS earth-to-space transmissions. However, there remains the possibility of an LMS transmitter beginning operation on a previously clear channel during the short interval of a MES transmission on that channel , and thereby potentially causing interference into the space station receiver.

## 2 Statistical modelling of interference from non-geostationary satellite orbit, mobile-satellite service, mobile earth stations (NGSO MSS MESs) into land mobile stations

The following statistical model determines the probability of interference without dynamic channel assignment being used. This worst case assumption provides an upper bound on the actual probability of interference for a single non-GSO MSS network with dynamic channel assignment.

The input parameters are:

a) Land Mobile Channelization Plan (25, 12.5 or 6.25 kHz) - Used to determine land mobile link centre frequency and receiver IF bandwidth as shown in Table 2-1.

TABLE 2-1

**Land Mobile Channelization Plans**

| Channelization Plan | IF Bandwidth |
|---|---|
| 25 kHz | 16 kHz |
| 12.5 kHz | 8 kHz |
| 6.25 kHz | 4 kHz |

b) MES Uplink Data Rate (9.6, 4.8, or 2.4 kbps) - Used to determine the MES transmit spectrum as shown in Figure 2-1 and transmit power as shown Table 2-2.

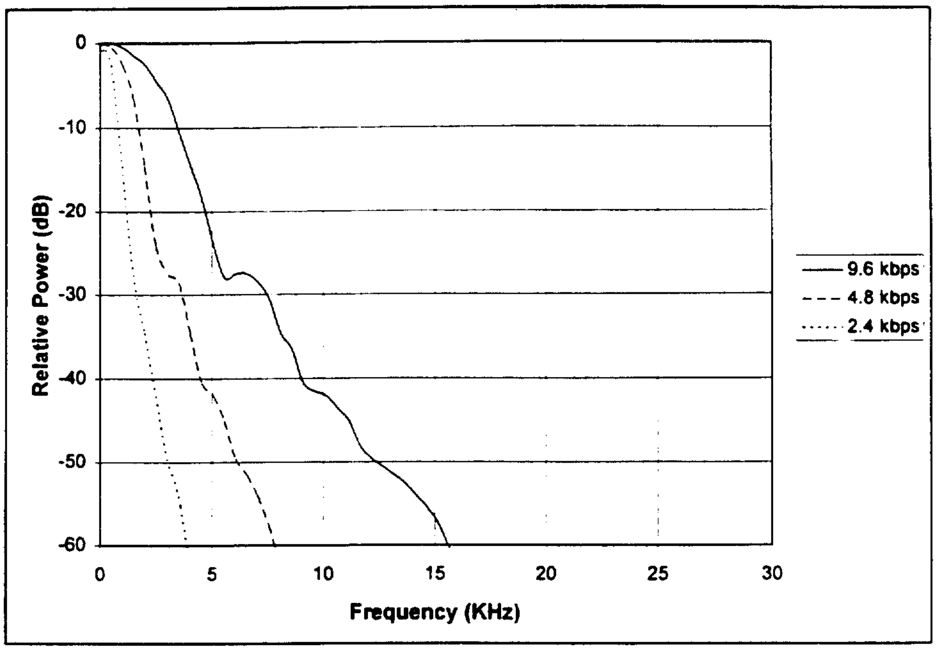


FIGURE 2-1

**MES Transmit Signal Masks**

TABLE 2-2

**MES Transmit Powers**

| Data Rate | Transmit Power* |
|---|---|
| 9.6 kbps | 7 W |
| 4.8 kbps | 3.5 W |
| 2.4 kbps | 1.75 W |
| *Transmit Power that provides -140 dBW at edge of coverage. | |

c) MES Distribution (Uniform or Clustered) - The uniform distribution models the MESs as uniformly distributed over the land area within the MSS satellite uplink beam. The clustered distribution places the MESs within the satellite beam with probability density roughly proportional to population density.

d) MES Channel Selection (Random or Interstitial) - For the random selection algorithm, the MSS uplink channels are selected randomly on a 2.5 kHz grid across the entire frequency band to be shared (1 MHz, for example). For the interstitial algorithm, the MSS uplink channels are restricted to interstitial locations between the land mobile channels.

For a given set of input parameters, a sufficient number of ½-second trials are performed to insure that the computed probability of interference is reliable. For each ½- second trial the following steps are performed:

1) A land mobile transmitter location is randomly selected as the centre of one of the 20 most populous cities within the MSS satellite uplink beam.

2) The land mobile receiver location is randomly selected using a circular mass distribution from 0 km to edge of coverage from the transmitter location.

3) A land mobile link centre frequency, $CF_{LM}$, is randomly selected in a 1 MHz bandwidth based on the input land mobile channelization plan.

4) The land mobile receiver IF bandwidth, $B_{IF}$, is determined from the input channelization plan.

5) The distance between the land mobile transmitter and the land mobile receiver, $d_{LM}$, is computed.

6) One hundred and twenty-eight active MESs are randomly selected each ½-second within the satellite beam using the input distribution, either uniform or clustered. This corresponds to over 22 million MES transmissions per day from the beam coverage area, which assumes that the NGSO MSS system is operating at 100% of theoretical capacity. This is another worst case assumption.

7) The distances, $d_{MES\text{-}LM}$, from each of the MESs to the land mobile receiver are computed.

8) Centre frequencies, $CF_{MES}$, are randomly selected in a 1 MHz band for each of the MESs using the input selected method, uniform or interstitial.

9) The MES effective isotropic radiated power spectrum, $EIRP_0(f)$, is determined based on the input data rate.

10) The carrier-to-noise-plus-interference ratio is computed as follows:

$$C/(N+I) = \frac{\dfrac{10^{3.204}\,W}{d_{LM}^4}}{10^{-15.07}\,W + \displaystyle\int_{CF_{LM}-\frac{B_{IF}}{2}}^{CF_{LM}+\frac{B_{IF}}{2}} \sum_{MESs} \frac{10^{2.815}\cdot EIRP_0(CF_{MES}-f)}{d_{MES-LM}^4}\,df}$$

This equation uses the propagation model in ITU-R Recommendation M.1039, with antenna heights of 1.5 m for both the LMS transmitter and receiver and for the MES transmitter.

11) If C/(N+I) is less then 10.7 dB then the trial is deemed to have resulted in interference.

The probability of interference is computed as the ratio of the number of trials resulting in interference divided by the total number of trials. This result is the probability of interference to the LMS receiver if it were to be receiving transmissions continuously.

For cases with low LMS traffic loading, the probability of interference is reduced by the Erlang factor for the channel.

## 3 Modelling of interference from land mobile stations into NGSO MSS satellites

Narrow-band non-GSO MSS networks will use dynamic channel assignment techniques to avoid channels being actively used by land mobile stations. Thus as long as the dynamic channel assignment system correctly identifies all active land mobile channels, there is no possibility of interference from land mobile stations into non-GSO MSS satellites. This model examines if there would be a sufficient number of unused, clear channels available to support non-GSO MSS operations.

The simulation determines the number of land mobile stations in the satellite beam that can operate in the shared spectrum and still provide an average of at least 6 channels per satellite for the NGSO MSS uplinks. This worst case assumption provides a lower bound on the number of land mobile stations that can operate in the shared spectrum while still allowing the NGSO MSS network to operate at 36% of theoretical capacity.

The input parameters are:

a) Land Mobile Channelization Plan (25, 12.5 or 6.25 kHz) - Used to determine land mobile station centre frequency grid, and land mobile transmit spectrum as shown in Figure 3-1.

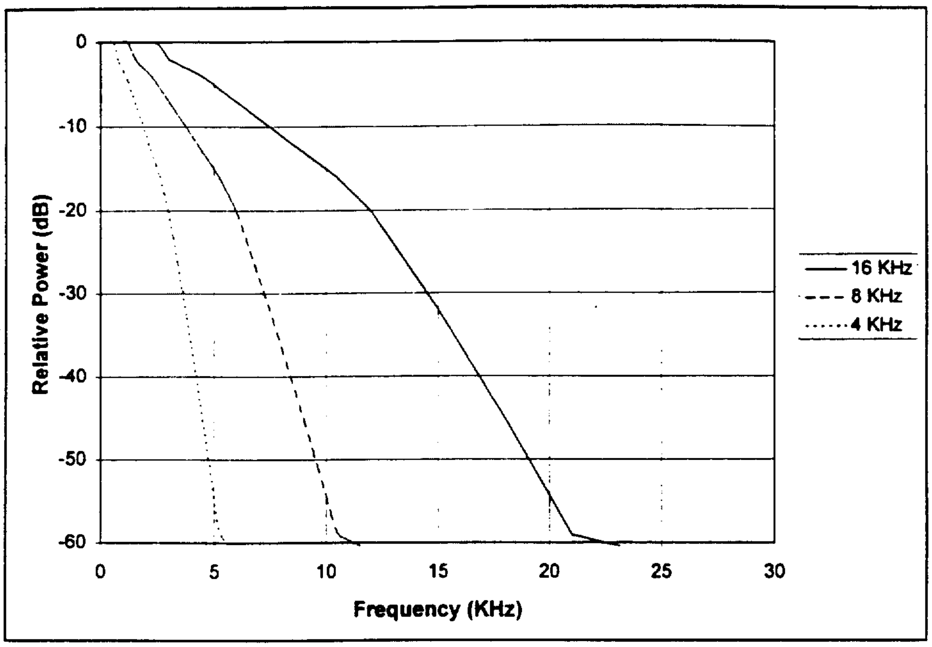


FIGURE 3-1

**Land Mobile Station Transmit Signal Masks**

b) MES Uplink Data Rate (9.6, 4.8, or 2.4 kbps) - Used to determine the NGSO MSS uplink centre frequency grid as shown in Table 3-1.

TABLE 3-1

**MES Uplink Channel Bandwidths**

| Data Rate | Channel Bandwidth |
|---|---|
| 9.6 kbps | 15 kHz |
| 4.8 kbps | 10 kHz |
| 2.4 kbps | 5 kHz |

c) Amount of shared spectrum (1 MHz or 5 MHz).

d) Land mobile station average activity factor (0.01, 0.003, 0.001, or 0.0003 Erlang).

For each set of input parameters, the following steps are performed:

1) The initial number of land mobile stations is set to 1 000.

2) The land mobile stations are randomly distributed across the area covered by the satellite uplink beam.

3) The land mobile transmitter effective isotropic radiated power spectrum, $EIRP_0(f)$ is determined based on the input land mobile channelization plan.

4) The NGSO MSS satellite system uplink channel bandwidth, BW, is determined based on the input MES uplink data rate.

5) For each trial, the NGSO MSS satellite constellation is randomly rotated in time, a sufficient number of trials are performed to insure that the computed number of land mobile stations is reliable. The following steps are performed:

   a) For each land mobile station, a transmit centre frequency, $CF_{LMS}$, is randomly selected in the input amount of shared spectrum, 1 MHz or 5 MHz, based on the input land mobile channelization plan.

   b) For each land mobile station and for each NGSO MSS satellite the Doppler frequency shift, $\Delta f_{Doppler}$, is computed taking account of the relative velocities of the transmit and receive equipments.

   c) For each NGSO MSS satellite and for each NGSO MSS uplink channel centre frequency, $CF_{CH}$, in the input amount of shared spectrum, the interference-to-noise ratio is computed as follows:

$$(I / N)_{CH} = 10^{6.25} \cdot \int_{CF_{CH}-\frac{BW}{2}}^{CF_{CH}+\frac{BW}{2}} \sum_{LMSs} EIRP_0(CF_{LMS} + \Delta f_{Doppler} - f)df$$

This equation uses the propagation model used in ITU-R Recommendation M.1039, for antenna heights of 1.5 m at both the LMS transmitter and receiver and the MES transmitter.

   d) For each NGSO MSS satellite, the number of clear channels is computed as the sum of those with I/N < 10 dB.

6) If the minimum of the computed numbers of clear channels is greater than 6, then the number of land mobile stations is increased by 1 000 and the above procedure is repeated starting at step 2.

7) The process is completed when the maximum number of LMS stations that still allows for 6 clear channels is found.

APPENDIX A

(To Annex 1)

**Example applications of the statistical models**

## 1 Introduction

This Appendix shows examples of application of the two statistical models contained in this Recommendation.

The example non-GSO MSS network used has the following characteristics: 48 satellites in 8 orbital planes inclined 50 degrees to the equator; each plane contains six equally spaced satellites in 950 km altitude circular orbits; narrow-band frequency division multiplexing for the Earth-to-space transmissions; operation in a store-and-forward mode; transmissions within 500 ms frames containing digital packets; satellite use of a band scanning receiver to implement a dynamic channel activity assignment system (DCAAS) that assigns unused channels to earth stations for uplink transmissions; and uplink data rates of 2.4, 4.8, and 9,6 kbps. It is assumed that the one MSS system is operating at maximum capacity over a specific geographic area, (for this example, 22 million Earth-to space packet transmissions per day over the contiguous United States).

The land mobile stations modelled have the following characteristics: analogue, frequency modulation system (or digitally modulated, binary-FSK system); a vertically polarized antenna having 0 dBi gain towards the satellite; minimum received signal power assumed to be -140 dBW; and channel bandwidths of 6.25, 12.5 and 25.0 kHz with low Erlang loading on individual channels. The technical characteristics used in the model are for certain LMS systems operating in the bands below 1 GHz.

## 2 Potential interference from non-GSO MSS earth stations into land mobile stations

The distance between the land mobile station and its base station is modelled by a circular mass distribution from 0 to 20 km with 20 km corresponding to threshold received power. Both uniform and clustered distribution of MSS earth stations are considered. A 1 MHz shared frequency band is assumed with both random and interstitial uplink channel selection algorithms considered.

Table A-1 shows the upper bound probability of interference computed by the simulation program for the range of parameters examined. The significance of the raw probabilities may be difficult to interpret, so they have been converted to mean time between interference events as shown in Table A-2. Results in Tables A-1 and A-2 are for the condition that the land mobile station is operating continuously. Table A-3 shows the mean time between interference events for a typical land mobile user with 0.01 Erlangs of traffic.

TABLE A-1

**Probability of Interference**

| **Land Mobile Channelization** | **MES Uplink Data Rate** | **Uniform Distribution** | | **Clustered Distribution** | |
|---|---|---|---|---|---|
| | | **Random Selection** | **Interstitial Selection** | **Random Selection** | **Interstitial Selection** |
| 25 kHz | 9.6 kbps | 0.00038 | 0.000055 | 0.0013 | 0.00020 |
| | 4.8 kbps | 0.00025 | 0.0000058 | 0.00088 | 0.000022 |
| | 2.4 kbps | 0.00016 | 0.00000093 | 0.00052 | 0.0000034 |
| 12.5 kHz | 9.6 kbps | 0.00023 | 0.00019 | 0.00075 | 0.00064 |
| | 4.8 kbps | 0.00012 | 0.000020 | 0.00039 | 0.000069 |
| | 2.4 kbps | 0.000067 | 0.0000024 | 0.00023 | 0.0000084 |
| 6.25 kHz | 9.6 kbps | 0.00014 | 0.00015 | 0.00049 | 0.00051 |
| | 4.8 kbps | 0.000094 | 0.00011 | 0.00032 | 0.00037 |
| | 2.4 kbps | 0.000066 | 0.000074 | 0.00023 | 0.00026 |

TABLE A-2

**Worst Case (Smallest) Mean Time Between Interference Events**

| **Land Mobile Channelization** | **MES Uplink Data Rate** | **Uniform Distribution** | | **Clustered Distribution** | |
|---|---|---|---|---|---|
| | | **Random Selection** | **Interstitial Selection** | **Random Selection** | **Interstitial Selection** |
| 25 kHz | 9.6 kbps | 22 min | *3 hours* | 7 min | 42 min |
| | 4.8 kbps | 34 min | *24 hours* | 10 min | *7 hours* |
| | 2.4 kbps | 50 min | *150 hours* | 16 min | *41 hours* |
| 12.5 kHz | 9.6 kbps | 36 min | 44 min | 11 min | 13 min |
| | 4.8 kbps | 70 min | *7 hours* | 22 min | 120 min |
| | 2.4 kbps | 130 min | *60 hours* | 36 min | *17 hours* |
| 6.25 kHz | 9.6 kbps | 60 min | 55 min | 17 min | 17 min |
| | 4.8 kbps | 90 min | 75 min | 26 min | 23 min |
| | 2.4 kbps | 130 min | 120 min | 36 min | 32 min |

TABLE A-3

**Mean Time Between Interference Events For Typical Push-to-Talk User (0.01 Erlang)**

| | | Uniform Distribution | | Clustered Distribution | |
|---|---|---|---|---|---|
| **Land Mobile Channelization** | **MES Uplink Data Rate** | **Random Selection** | **Interstitial Selection** | **Random Selection** | **Interstitial Selection** |
| 25 kHz | 9.6 kbps | *37 hours* | 10 days | *11 hours* | *69 hours* |
| | 4.8 kbps | *56 hours* | 100 days | *16 hours* | 26 days |
| | 2.4 kbps | *83 hours* | ***21 months*** | *27 hours* | 68 days |
| 12.5 kHz | 9.6 kbps | *60 hours* | *73 hours* | *18 hours* | *22 hours* |
| | 4.8 kbps | *120 hours* | 29 days | *36 hours* | *200 hours* |
| | 2.4 kbps | *210 hours* | ***8 months*** | *60 hours* | 71 days |
| 6.25 kHz | 9.6 kbps | *100 hours* | *92 hours* | *28 hours* | *28 hours* |
| | 4.8 kbps | *150 hours* | *130 hours* | *43 hours* | *38 hours* |
| | 2.4 kbps | *210 hours* | *190 hours* | *60 hours* | *53 hours* |

For land mobile channelizations, MES uplink data rates, and other parameters that are different from those used in this example, interpolation may be used to determine approximate values of probabilities of interference and mean times between interference events.

## 3 Potential interference from land mobile stations into non-GSO MSS satellites

The model of Section 3 of the annex of this recommendation performs a simulation to determine the number of land mobile stations within the MSS satellite uplink beam that can operate in the shared spectrum and still provide an average of at least 6 channels per satellite for the MSS uplinks. The average per satellite assumption is worst case, since the average over all of the visible satellites will be greater than the average per satellite, and thus provides a lower bound on the number of land mobile stations that can operate in the shared spectrum. The satellite footprint is roughly the size of the contiguous United States, 12 million km$^2$.

Four land mobile station average activity factors were considered, 0.01, 0.003, 0.001, and 0.0003 Erlang[1]. These correspond to averages of 432, 130, 43, and 13 minutes per month of land mobile station transmissions, respectively. Assuming a 0.4 voice activity factor, the equivalent conversation times are 1,080, 325, 108, and 33 minutes per month. Note that the averages are over the entire population of land mobile stations and over the entire month.

[1] Erlang is a measure of traffic intensity. In this context it is a measure of the land mobile station utilization.

Table A-4 shows lower bounds on the number of land mobile stations in the contiguous United States operating in 1 MHz of shared spectrum computed by the simulation program for the range of parameters examined.

Table A-5 shows the lower bounds assuming 5 MHz of shared spectrum. The lower bounds are significantly greater than 5 times those for 1 MHz of shared spectrum.

TABLE A-4

**Lower Bound Number of Land Mobile Stations in 1 MHz of Shared Spectrum**

| | | **Land Mobile Station Average Activity Factor** | | | |
|---|---|---|---|---|---|
| **Land Mobile Channelization** | **MES Uplink Data Rate** | **0.01 Erlang** | **0.003 Erlang** | **0.001 Erlang** | **0.0003 Erlang** |
| 25 kHz | 9.6 kbps | 12,000 | 38,000 | 120,000 | 380,000 |
| | 4.8 kbps | 17,000 | 55,000 | 170,000 | 550,000 |
| | 2.4 kbps | 23,000 | 77,000 | 230,000 | 770,000 |
| 12.5 kHz | 9.6 kbps | 16,000 | 52,000 | 160,000 | 520,000 |
| | 4.8 kbps | 24,000 | 80,000 | 240,000 | 800,000 |
| | 2.4 kbps | 35,000 | 120,000 | 350,000 | 1.2 million |
| 6.25 kHz | 9.6 kbps | 18,000 | 60,000 | 180,000 | 600,000 |
| | 4.8 kbps | 35,000 | 120,000 | 350,000 | 1.2 million |
| | 2.4 kbps | 58,000 | 190,000 | 580,000 | 1.9 million |

TABLE A-5

**Lower Bound Number of Land Mobile Stations in 5 MHz of Shared Spectrum**

| Land Mobile Channelization | MES Uplink Data Rate | Land Mobile Station Average Activity Factor | | | |
|---|---|---|---|---|---|
| | | **0.01 Erlang** | **0.003 Erlang** | **0.001 Erlang** | **0.0003 Erlang** |
| 25 kHz | 9.6 kbps | 110,000 | 370,000 | 1.1 million | 3.7 million |
| | 4.8 kbps | 125,000 | 420,000 | 1.3 million | 4.2 million |
| | 2.4 kbps | 170,000 | 570,000 | 1.7 million | 5.7 million |
| 12.5 kHz | 9.6 kbps | 115,000 | 380,000 | 1.2 million | 3.8 million |
| | 4.8 kbps | 190,000 | 630,000 | 1.9 million | 6.3 million |
| | 2.4 kbps | 255,000 | 850,000 | 2.6 million | 8.5 million |
| 6.25 kHz | 9.6 kbps | 120,000 | 400,000 | 1.2 million | 4.0 million |
| | 4.8 kbps | 230,000 | 770,000 | 2.3 million | 7.7 million |
| | 2.4 kbps | 450,000 | 1.5 million | 4.5 million | 15 million |

For parameter values not presented in the tables, interpolation may be used to determine approximate values of the lower bound numbers.

INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION
STUDY GROUPS

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**Sub-Draft' ıg Group 8D3A-5**

ATTACHMENT TO WORKING PARTY 8D CHAIRMAN'S REPORT

**FREQUENCY SHARING BETWEEN NON-GSO MSS (NARROW-BAND EARTH-TO-SPACE LINKS) BELOW 1 GHz AND LMS SYSTEMS**

## 1 Introduction

Resolution 214 (WRC-95) *resolves*

1) "that further studies are urgently required on operational and technical means to facilitate sharing between the non-GSO/MSS and other radiocommunication services having allocations and operating below 1 GHz;" and

2) "that the 1997 World Radiocommunication Conference (WRC-97) be invited to consider, on the basis of the results of the studies referred to in resolves 1 above, additional allocations on a worldwide basis for the non-GSO/MSS below 1 GHz."

This paper presents results of studies that show the feasibility of non-geostationary orbit mobile satellite service (non-GSO MSS) systems (narrow-band Earth-to-space links) sharing the same frequency band with mobile transceivers in Land Mobile Service (LMS) systems. The analyses in this paper include digitally modulated LMS systems, and the analyses are applied using LMS system characteristics common to several frequency bands below 1 GHz.

Section 2 characterizes the sharing environment. Section 3 describes a channel assignment method that allows the satellite system to occupy channels that are temporarily unused by the LMS systems. Later subsections present probability of interference results that show the potential interference to be rare. Preliminary draft new Recommendation, "Method for the statistical modelling of frequency sharing between stations in the land mobile service below 1 GHz and FDMA non-geostationary satellite orbit (non-GSO) mobile earth stations", [8D/TEMP/xyz, Attachment 1] incorporates the statistical modelling techniques for LMS/MSS sharing presented in this analysis.

## 2 Sharing environment

The 148 - 149.9 MHz, 455 - 456 MHz, and 459 - 460 MHz bands are currently allocated for non-GSO MSS uplinks and for land mobile service links on a co-primary basis. Other bands below 1 GHz that are allocated to the land mobile service are also being considered for allocation to the non-GSO MSS on a co-primary basis. Thus there is the potential for interference, both from non-

GSO MSS Mobile Earth Stations (MESs) into land mobile stations and from land mobile stations into non-GSO MSS satellites.

## 2.1 Non-GSO MSS network

The example non-GSO MSS network used in the analysis has the following characteristics: 48 satellites in 8 orbital planes inclined 50 degrees to the equator; each plane contains six equally spaced satellites in 950 km altitude circular orbits; narrow-band frequency division multiplexing for the Earth-to-space transmissions; operation in a store-and-forward mode; transmissions within 500 ms frames containing digital packets; satellite use of a band scanning receiver to implement a dynamic channel activity assignment system (DCAAS) that assigns unused channels to earth stations for uplink transmissions; and uplink data rates of 2.4, 4.8, and 9.6 kbps. For the analysis it was assumed that the system was operating at maximum capacity over a specific geographic area, (for this study, 22 million Earth-to-space packet transmissions per day over the contiguous United States).

## 2.2 Land mobile system

The land mobile stations used in this analysis have the following characteristics: analogue, frequency modulation system (or digitally modulated, binary-FSK system); a vertically polarized antenna having 0 dBi gain towards the satellite; minimum received signal power assumed to be -140 dBW; and channel bandwidths of 6.25, 12.5 and 25.0 kHz. Additionally, low erlang loading (0.01 to 0.0003) on individual channels provides opportunity for short-term, intermittent use of the frequencies by the mobile satellite earth stations.

## 3 Band sharing using dynamic channel assignment techniques

Mobile satellite systems below 1 GHz can use the technique of dynamic channel assignment to allow mobile earth stations to communicate effectively in the presence of approximately co-channel uplink interference from mobile transmitters. A receiver in the satellite monitors the entire shared frequency band and determines which segments of the spectrum are currently being used by the LMS system or for non-GSO MSS uplinks. The identified clear channels are available for assignment to non-GSO MSS uplinks. The LEO-L MSS system design uses a digital dynamic channel assignment technique that performs Fast Fourier Transform (FFT) processing in the satellite which allows the MSS uplink channels to be re-assigned (of the order of every 0.5 s) in response to measured channel availability. The digital band-scanning receiver to be used by one non-GSO MSS system can detect a 0.5 second duration, 460 MHz, 2.5 kHz bandwidth, 3.5 mW transmit power signal anywhere in the satellite footprint with 99.9% probability. For a 16 kHz signal the sensitivity is 22 mW. At 149 MHz the transmit power sensitivities are 0.4 mW and 2.3 mW, for 2.5 kHz and 16 kHz signals, respectively.

### 3.1 Operation of dynamic channel assignment techniques

With the band-scanning receiver on board the satellite, there is very little chance for interference from mobile earth stations to land mobile system receivers. There are, however, several circumstances where the dynamic channel assignment technique would fail to identify an active LMS channel:

1) LMS power level below the detection threshold of the satellite band-scanning receiver;

2) blockage on the path from the LMS transmitter to the satellite so the received signal level is not high enough to be detected;

3) a LMS transmitter begins operation on a channel during a MSS transmission on what had previously been measured as a clear channel.

Analyses have been performed at 149 and 460 MHz to calculate the probability of interference to a LMS receiver from MES transmissions, given that the dynamic channel assignment technique has failed to identify an active channel for the reasons given above, or for any other reason. The results apply to both analogue and digitally modulated LMS systems, operating in the bands 138 - 174 MHz, 406 - 420 MHz, 450 - 512 MHz, 806 - 821 MHz, 821 - 824 MHz, 851 - 856 MHz, and 866 - 869 MHz, provided that the technical characteristics are consistent with those used in the model.

### 3.2 Potential interference from non-GSO MSS earth stations into land mobile stations

The analysis assumed multiple worst case conditions:

1) non-GSO MSS mobile earth stations (MESs) transmitting at 100% of capacity, 24 hours per day;

2) terrestrial stations and non-GSO MSS MESs geographically clustered in the same areas; and

3) dynamic channel avoidance not effective. A Working Party 8D Preliminary draft new Recommendation [Document WP8D/TEMP/xyz, Attachment 1] describes the modelling and simulations used in the analyses.

For the worst case conditions stated, if the land mobile station is operated at push-to-talk rates of 0.01 erlang, the land mobile station would experience a mean time between interference events of 11 hours. For a variety of channelization plans, MES bit rates, and terminal distributions, the mean time between interference events for a typical land mobile user was found to range from 11 hours to 21 months. The analogue FM land mobile user would observe the interference event as a single "click" or "pop". For digital FSK receivers, operation below the demodulator threshold results in an increased bit-error rate and degraded voice quality. Since in general the non-GSO MSS network will be able to identify active mobile channels, the actual interference from non-GSO MSS MESs into a given land mobile station will be much less than that calculated under the worst case assumptions used.

The results of the analysis are now used to calculate the probability of interference with dynamic channel assignment in use. For the case of a low power LMS system where the transmitter power is not high enough to be detected by the band-scanning receiver, the interference probabilities would be as calculated using the methods of PDNR [WP8D/TEMP/xyz, Attachment 1]. For the case of signal blockage causing the dynamic channel assignment technique to not identify an active channel, the interference probability would be as calculated in the previous paragraph but multiplied by $p_b$ (the probability of signal blockage). $p_b$ is certainly less than one, and may typically be in the range 0.1-1.0%. For the case of a LMS transmitter beginning operation in what had previously been a clear channel, the interference probability would be as calculated in the previous paragraph but multiplied by $p_c$ (the probability of a free channel being used by a MES and then also being selected for use by an LMS system). $p_c$ is less than one, and may be in the range 0.1 to 0.25). Thus, in the identified cases where the dynamic channel assignment technique fails to fully prohibit the possibility of interference, the probability of interference from MES transmitters to LMS mobile receivers may be acceptably low, for LMS systems that can accept 0.1% additional degradation of availability. While the analyses were performed using mobile transceivers in the LMS with an antenna height product of 10 meters (as indicated in ITU-R Recommendation M.1039-1), the results also apply to non-GSO MSS sharing with fixed LMS transceivers that have the same technical characteristics, including the antenna height product.

### 3.2.1 Effects of interference into LMS receivers

For land mobile systems, circuit availability may range from 90 to 99%, with the higher values applicable to critical communications such as fire or safety. Availability degradation of an additional 0.1% due to NGSO MSS shared use of frequency bands may be considered acceptable by some users. For 100 ms transmissions by the NGSO MSS, this would translate to one interference event every 100 seconds, or approximately once every 2 minutes.

The short duration of potential non-GSO MSS interference into LMS receivers further mitigates the effects of the interference. A 100 millisecond interference into analogue voice may not affect message intelligibility, and for digital systems, the short interference burst may be eliminated by some error correction techniques.

### 3.3 Interference from land mobile stations into non-GSO MSS satellites

Narrow-band non-GSO MSS networks will use dynamic channel assignment techniques to avoid channels being actively used by land mobile stations. Thus as long as the dynamic channel assignment system correctly identifies all active land mobile channels, there is no possibility of interference from land mobile stations into non-GSO MSS satellites. An analyses using the modelling techniques of PDNR 8D/TEMP/xyz, Attachment 1 examined if there would be a sufficient number of unused, clear channels available to support non-GSO MSS operations.

A simulation program was used to determine the number of land mobile stations within the satellite footprint that can operate in the shared spectrum and still provide a minimum average of 6 clear channels per satellite for the non-GSO MSS uplinks. Four different land mobile station activity factors, three land mobile channelization plans, and three MES uplink data rates were considered. The results indicate that with 6.25 kHz land mobile system channelization, 2.4 kbps MES uplink data rate, and 0.003 erlang activity factor, 190 000 terrestrial mobile stations could operate within the satellite footprint (12 million $km^2$) and still leave a minimum of 6 clear channels for MES uplink transmission in 1 MHz of shared bandwidth. For the same conditions, but in 5 MHz of shared bandwidth, 1.5 million terrestrial mobile stations could operate.

These results indicate that frequency sharing, as modelled in this analysis, could allow the non-GSO MSS below 1 GHz networks to find sufficient clear channels to operate.

## 4 Conclusions

The results of these analyses and simulations show that frequency sharing between narrow-band, Earth-to-space links for non-GSO MSS below 1 GHz networks and land mobile services would produce infrequent interference to the land mobile service in frequency bands below 1 GHz, with LMS characteristics as modelled. An additional result is that frequency sharing between narrow-band non-GSO MSS below 1 GHz networks and land mobile services could allow the non-GSO MSS networks to find sufficient clear channels to operate Earth-to-space. The conclusion is that it is feasible for narrow-band non-GSO MSS uplinks (using dynamic channel assignment techniques to share spectrum with land mobile services in the bands below 1 GHz that have low erlang levels in the LMS and for services that accept an additional 0.1% availability degradation. Further study, however, may be necessary to ascertain the effects to terrestrial mobile relay systems where characteristics of the terrestrial systems may be different than modelled in this analysis.

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WORKING DOCUMENT TOWARD
A PRELIMINARY DRAFT NEW RECOMMENDATION
AND DRAFT CPM REPORT TEXT

**FREQUENCY SHARING BETWEEN NON-GSO MSS (NARROWBAND EARTH-TO-SPACE LINKS) AND LMS SYSTEMS**

## 1. Introduction

Resolution 214 (WRC-95) resolves 1) "that further studies are urgently required on operational and technical means to facilitate sharing between the non-GSO/MSS and other radiocommunication services having allocations and operating below 1GHz;" and 2) "that the 1997 World Radiocommunication Conference (WRC-97) be invited to consider, on the basis of the results of the studies referred to in resolves 1 above, additional allocations on a worldwide basis for the non-GSO/MSS below 1 GHz." This paper presents results of studies that show the feasibility of non-geostationary orbit mobile satellite service (non-GSO MSS) systems (narrowband earth-to-space links) sharing the same frequency band with mobile transceivers in land mobile service (LMS) systems. This paper is an expansion of a previous submission to WP 8D in that digitally modulated LMS systems are included in the analysis, and the analysis is applied using LMS system characteristics common to several frequency bands below 1 GHz.

Section 2 characterizes the sharing environment. Section 3 describes a channel assignment method that allows the satellite system to occupy channels that are temporarily unused by the LMS systems. Later subsections present probability of interference results that show the potential interference to be rare. Annex 1 to this paper presents a Preliminary Draft New Recommendation, "Method for the Statistical Modeling of Frequency Sharing Between Stations in the Mobile Service Below 1 GHz and FDMA Non-Geostationary Satellite Orbit (Non-GSO) Mobile Earth Stations", which incorporates the statistical modeling techniques for LMS/MSS sharing presented in this paper. Annex 2 to the paper presents draft modifications to Recommendation M.1039, "Co-Frequency Sharing Between Stations in the Mobile Service Below 1 GHz and FDMA Non-Geostationary-Satellite Orbit (Non-GSO) Mobile Earth Stations." Annex 3 is the detailed analysis that supports the PDNR in Annex 1 and presents the statistical modeling and simulation results that demonstrate low probabilities of interference. Performance of a digital dynamic channel assignment technique is also given in Annex 3. Annex 4 provides draft CPM Report text for section 4.1.1.1 on the subject of LMS/MSS frequency sharing below 1 GHz.

## 2. Sharing environment

The 148-149.9 MHz, 455-456 MHz, and 459-460 MHz bands are currently allocated for non-GSO MSS uplinks and for land mobile service links on a co-primary basis. Other bands below 1 GHz that are allocated to the land mobile service are also being considered for allocation to the non-

GSO MSS on a co-primary basis. Thus there is the potential for interference, both from non-GSO MSS Mobile Earth Stations (MESs) into land mobile stations and from land mobile stations into non-GSO MSS satellites.

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Mobile satellite systems below 1 GHz can use the technique of dynamic channel assignment to allow mobile earth stations to communicate effectively in the presence of approximately co-channel uplink interference from mobile transmitters. A receiver in the satellite monitors the entire shared frequency band and determines which segments of the spectrum are currently being used by the LMS system or for non-GSO MSS uplinks. The identified clear channels are available for assignment to non-GSO MSS uplinks. The LEO-L MSS system design uses a digital dynamic channel assignment technique that performs fast Fourier transform (FFT) processing in the satellite which allows the MSS uplink channels to be re-assigned (of the order of every 0.5 s) in response to measured channel availability. The band-scanning receiver sensitivity analysis in Appendix A of Annex 3 shows that the band-scanning receiver to be used by LEO-L can detect a 0.5 second duration, 460 MHz, 2.5 kHz bandwidth, 3.5 mW transmit power signal anywhere in the satellite footprint with 99.9% probability. For a 16 kHz signal the sensitivity is 22 mW. At 149 MHz the transmit power sensitivities are 0.4 mW and 2.3 mW, for 2.5 kHz and 16 kHz signals, respectively.

### 3.1 Operation of dynamic channel assignment techniques

With the band-scanning receiver on board the satellite, there is very little chance for interference from mobile earth stations to land mobile system receivers. There are, however, several circumstances where the dynamic channel assignment technique would fail to identify an active LMS channel: 1) LMS power level below the detection threshold of the satellite band-scanning receiver, 2) blockage on the path from the LMS transmitter to the satellite so the received signal level is not high enough to be detected, 3) a LMS transmitter begins operation on a channel during a MSS transmission on what had previously been measured as a clear channel.

Annex 3, "NVNG MSS Uplink Band Sharing Analysis" provides calculation of the probability of interference to a LMS receiver from MES transmissions, given that the dynamic channel assignment technique has failed to identify an active channel for the reasons given above, or for any other reason. The results apply to both analog and digitally modulated LMS systems, operating in the bands 138-174 MHz, 406-420 MHz, 450-512 MHz, 806-821 MHz, 821-824 MHz, 851-856 MHz, and 866-869 MHz, provided that the technical characteristics are consistent with those used in the model.

### 3.2 Potential interference from non-GSO MSS earth stations into land mobile stations

The analysis assumed multiple worst case conditions: 1) non-GSO MSS mobile earth stations (MESs) transmitting at 100% of capacity, 24 hours per day, 2) terrestrial stations and non-GSO MSS MESs geographically clustered in the same areas, and 3) dynamic channel avoidance not effective. Appendix B of Annex 3 describes the modeling and simulations used in the analyses.

For the worst case conditions stated, if the land mobile station is operated at push-to-talk rates of 0.01 Erlang, the land mobile station would experience a mean time between interference events of 2.5 days. For a variety of channelization plans, MES bit rates, and terminal distributions, the mean time between interference events for a typical land mobile user was found to range from 10 hours to 21 months. The analog FM land mobile user would observe the interference event as a single "click" or "pop". For digital FSK receivers, operation below the demodulator threshold results in an increased bit error rate and degraded voice quality. Since in general the non-GSO MSS network will be able to identify active mobile channels, the actual interference from non-GSO MSS MESs into a given land mobile station will be much less than that calculated under the worst case assumptions used.

The results of the analysis are now used to calculate the probability of interference with dynamic channel assignment in use. For the case of a low power LMS system where the transmitter power is not high enough to be detected by the band-scanning receiver, the interference probabilities would be as calculated in Annex 3. For the case of signal blockage causing the dynamic channel assignment technique to not identify an active channel, the interference probability would be as calculated in Annex 3 but multiplied by $p_b$ (the probability of signal blockage.) $p_b$ is certainly less than one, and may typically be in the range 0.1-1.0%. For the case of a LMS transmitter beginning operation in what had previously been a clear channel, the interference probability would be as calculated in Annex 3 but multiplied by $p_c$ (the probability of a free channel being used by a MES and then also being selected for use by an LMS system). $p_c$ is less than one, and may be in the range 0.1 to 0.25). Thus, in the identified cases where the dynamic channel assignment technique fails to fully prohibit the possibility of interference, the probability of interference from MES transmitters to LMS mobile receivers may be acceptably low, for LMS systems that can accept 0.1% additional degradation of availability. While the analyses were performed using mobile transceivers in the LMS with an antenna height product of 10 meters (as indicated in ITU-R Recommendation M.1039-1), the results also apply to non-GSO MSS sharing with fixed LMS transceivers that have the same technical characteristics, including the antenna height product.

#### 3.2.1 Effects of interference into LMS receivers

For land mobile systems, circuit availability may range from 90 to 99%, with the higher values applicable to critical communications such as fire or safety. Availability degradation of an additional 0.1% due to NGSO MSS shared use of frequency bands may be considered acceptable by some users. For 100 ms transmissions by the NGSO MSS, this would translate to one interference event every 100 seconds, or approximately once every 2 minutes.

The short duration of potential non-GSO MSS interference into LMS receivers further mitigates the effects of the interference. A 100 millisecond interference into analog voice may not affect message intelligibility, and for digital systems, the short interference burst may be eliminated by some error correction techniques.

### 3.3 Interference from land mobile stations into non-GSO MSS satellites

Narrowband non-GSO MSS networks will use dynamic channel assignment techniques to avoid channels being actively used by land mobile stations. Thus as long as the dynamic channel assignment system correctly identifies all active land mobile channels, there is no possibility of interference from land mobile stations into non-GSO MSS satellites. The analysis in Annex 3 section 4 examined if there would be a sufficient number of unused, clear channels available to support non-GSO MSS operations.

A simulation program was used to determine the number of land mobile stations within the satellite footprint that can operate in the shared spectrum and still provide a minimum average of 6 clear channels per satellite for the non-GSO MSS uplinks. Four different land mobile station activity factors, three land mobile channelization plans, and three MES uplink data rates were considered. The results indicate that with 6.25 kHz land mobile system channelization, 2.4 kbps MES uplink data rate, and 0.003 Erlang activity factor, 190 000 terrestrial mobile stations could operate within the satellite footprint (12 million $km^2$) and still leave a minimum of 6 clear channels for MES uplink transmission in 1 MHz of shared bandwidth. For the same conditions, but in 5 MHz of shared bandwidth, 1.5 million terrestrial mobile stations could operate.

These results indicate that frequency sharing, as modeled in this analysis, could allow the non-GSO MSS below 1 GHz networks to find sufficient clear channels to operate.

## 4. Conclusions

The results of these analyses and simulations show that frequency sharing between narrowband, Earth-to-space links for non-GSO MSS below 1 GHz networks and land mobile services would produce infrequent interference to the land mobile service in frequency bands below 1 GHz, with LMS characteristics as modeled. An additional result is that frequency sharing between narrowband non-GSO MSS below 1 GHz networks and land mobile services could allow the non-GSO MSS networks to find sufficient clear channels to operate Earth-to-space. The conclusion is that it is feasible for narrowband non-GSO MSS uplinks using DCAAS to share spectrum with land mobile services in the bands below 1 GHz that have low erlang levels in the LMS and for services that accept an additional 0.1% availability degradation. Further study, however, may be necessary to ascertain the effects to terrestrial mobile relay systems where characteristics of the terrestrial systems may be different than modeled in this analysis.

Based upon these results a preliminary draft new recommendation is given in Annex 1, and, draft modifications to ITU-R Recommendation M. 1039 are provided in Annex 2.